TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909

INCORPORATED 1930

CONTENTS

Page

Air-Cooled High Intensity High Pressure Mercury Vapour Lamps, by V. J. Francis, B.Sc., M.I.E.E., A.R.C.S., F.Inst.P. - - - 315

Additions to List of Members - 327

Special Lighting Units for the Flight Decks of Aircraft Carriers, by H. H. Matthews *(Member)* - - - 328

Register of Lighting Engineers - 334

VOLUME XV
No. 9 — 1950

32 VICTORIA ST
LONDON, SW1

Annual Subscription to Non-Members - £2.2.0
Price per Number to Non-Members - 5s. 0d.

The I.E.S Council and Committees

Session 1950-1951

Council

President:—L. J. DAVIES, B.Sc., M.A. (*Fellow*).

Vice-Presidents:—C. R. BICKNELL, B.Sc. (*Fellow*), J. G. HOLMES, B.Sc. (*Fellow*), W. R. STEVENS, B.Sc. (*Fellow*).

Members of Council:—

Elected Members:—

A. D. S. ATKINSON, H. S. BARLOW, G. G. BAINES, S. S. BEGGS, H. G. CAMPBELL, W. J. WELLWOOD FERGUSON, G. H. GILES, H. F. GILLBE, W. E. HARPER, A. G. HIGGINS, R. G. HOPKINSON, C. A. HOSKINS, A. W. JERVIS, E. C. LENNOX, L. H. MCDERMOTT, A. G. PENNY, L. C. RETTIG, E. B. SAWYER, SIR HENRY SELF, W. T. F. SOUTER, W. S. STILES, D. A. STRACHAN, S. G. TURNER, W. J. P. WATSON.

Ex-Officio Representatives of Centres:—

H. J. WESTON (*Bath and Bristol*), F. PENSON (*Birmingham*), D. C. JAMES (*Cardiff*), H. D. PURVIS (*Edinburgh*), F. DUNNETT (*Glasgow*), I. R. MORGAN (*Gloucester and Cheltenham*), J. W. HOWELL (*Leeds*), R. K. L. DAVIES (*Leicester*), T. D. WOODS (*Liverpool*), W. G. CHILVERS (*Manchester*), J. S. MCCULLOCH (*Newcastle*), G. C. SMALL (*Nottingham*), J. A. WHITTAKER (*Sheffield*).

Hon. Treasurer:—
W. J. JONES.

Hon. Secretary:—
H. C. WESTON.

Hon. Editor of Transactions:—W. R. STEVENS.

All Past-Presidents of the Society are *ex-officio* Members of Council.

Committees

GENERAL PURPOSES COMMITTEE: L. J. Davies (*President*), C. R. Bicknell, J. G. Holmes, W. R. Stevens (*Vice-Presidents*), W. J. Jones (*Hon. Treasurer*), H. C. Weston (*Hon. Secretary*), J. N. Aldington (*Past-President*), J. W. Howell (*Leeds Centre*), G. C. Small (*Nottingham Centre*).

PAPERS COMMITTEE: A. D. S. Atkinson, H. G. Campbell, W. E. Harper, R. G. Hopkinson, W. T. F. Souter, W. S. Stiles, J. M. Waldram.

EDUCATION COMMITTEE: R. O. Ackerley, G. G. Baines, H. S. Barlow, S. S. Beggs, A. Cunnington, W. J. Jones, J. T. MacGregor-Morris, F. C. Smith, W. R. Stevens, J. W. T. Walsh.

I.E.S. CODE COMMITTEE: R. O. Ackerley, E. B. Sawyer, F. C. Smith, W. T. F. Souter, W. S. Stiles, H. C. Weston.

CENTRES JOINT COMMITTEE: One representative from each Centre. Council's Representatives: C. R. Bicknell, E. B. Sawyer, W. R. Stevens.

(The President, Hon. Secretary and Hon. Treasurer are *ex-officio* members of all committees.)

Secretary:—G. F. COLE, 32, Victoria-street, London, S.W.1.

Air-Cooled High Intensity High Pressure Mercury Vapour Lamps

By V. J. FRANCIS, B.Sc., M.I.E.E., A.R.C.S., F.Inst.P.

Summary

During and since the war there have been important developments in high pressure mercury vapour lamps. As a result much more is now known of the properties of lamps with high power loading per centimetre of arc than was the case ten years ago. As well as significant progress with small source high brightness lamps proper, there has emerged intermediate between these and the older tubular lamps a design of lamp with luminous efficiencies greater than those previously obtainable. Useful progress has been made also with the colour rendering properties and new applications are in consequence being found.

Contents

(1) INTRODUCTION AND HISTORICAL SUMMARY.

(2) PROPERTIES OF THE DISCHARGE.
- (2.1) Luminous Efficiency.
- (2.2) Brightness.
- (2.3) Colour Rendering Properties.

(3) LAMPS.
- (3.1) General.
- (3.2) High Efficiency Lamps for General Illumination.
- (3.3) High Brightness Lamps.
- (3.4) Colour Modified Lamps.

(4) OPERATING CHARACTERISTICS.
- (4.1) Arc Voltage Drop.
- (4.2) Run-up Time.
- (4.3) Hut Restarting.

(5) APPLICATIONS.
- (5.1) Film Projection.
- (5.2) Film Studio Illumination.
- (5.3) High Bay Lighting.

(1) Introduction and Historical Summary

In the ten years before the outbreak of the second world war the high pressure mercury vapour (h.p.m.v.) lamp had established itself as an efficient light source for general illumination, at least in circumstances—such as for street lighting, and for certain industrial applications—where colour rendering was not of great importance.

A range of lamps with hard glass envelopes of ratings from some 200 watts to 1-kw. was in use, with efficiencies ranging from about 35 lumens per watt to 50 lumens per watt. The impracticability of obtaining high luminous efficiencies in ratings much below 200 watts had led to the development of lamps using quartz inners, covering the range 40-150 watts. The envelopes of these lamps, as for those of the the glass lamps mentioned above, were tubular in shape; that is, the arc length was long compared with the diameter of the tube (Fig. 1a and 1b.).

The use of the h.p.m.v. lamp as a high brightness source had been investigated with much interest in the few years before 1939. Linear water-cooled lamps had been made available in 500-watt, 1-kw. and 2-kw. ratings, and their use was being explored for the projection of films [1] [10]. The other type of high brightness source, which has become generally known as the compact source lamp (Fig. 1c.), was then also available in the smaller sizes, 250-watt and 500-watt for example [2].

Although at this time a vastly better understanding of the properties of the h.p.m.v. discharge had been obtained by the work of the previous five years or so, there was still much to be learned. It was not known, for example, what were the highest luminous

Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley, England. This paper was presented at the eleventh session of the International Commission on Illumination in Paris, June-July, 1948.

efficiencies obtainable, either ideally or in practice, and still less was it known what would prove to be the limitations in its use for high brightness lamps. Were there fundamental limitations in the brightness that could be obtained, or would these limits be set by practical considerations of lamp design? If so, what particular difficulties would be found to be the limiting factors?

It is difficult to assess the influence that the war had on the course of development. Certainly it tended to slow down progress in the use of h.p.m.v. lamps for general lighting purposes—assisted by the advent of the low-pressure mercury tubular fluorescent lamp, which rapidly became widely used for industrial lighting—and in some respects may have speeded the exploration of their possibilities as high brightness sources.

During and since the war there has been little change in the technical position of the tubular lamps. The main progress has been the clarification of their limitations,

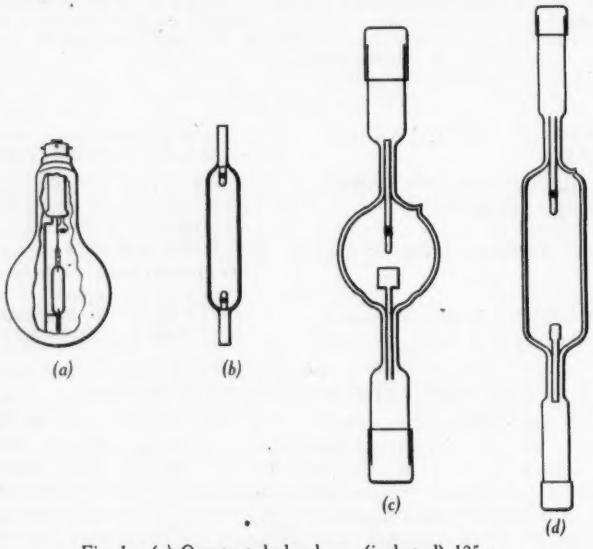

Fig. 1. (*a*) Quartz tubular lamp (jacketed) 125w.
(*b*) Quartz tubular lamp 1 kw.
(*c*) High brightness lamp 5 kw.
(*d*) High efficiency lamp 5 kw.

and a better understanding of the considerations involved in their widespread commercial application. No great difficulty has been found in extending the range of tubular quartz lamps to higher wattages, although in the larger ratings their gain over the corresponding glass lamps is not very large. The extent of the future use of the tubular quartz lamp will be determined—apart, of course, from the difficulty of colour, which is general in all h.p.m.v. lamps—by economic factors and the extent to which the higher efficiency of the quartz lamps compensates for their higher cost. In the smaller ratings the balance is in favour of the quartz lamps. It is not so evident in larger ratings. Little progress has been made in the improvement of the colour rendering of such lamps. The one possibility which might have led to a rapid commercial development of this class of lamp is the association of fluorescent powders with the discharge to effect a substantial improvement in colour. This is a field perhaps comparatively unexplored. There are obvious difficulties, some of them rather funda-

mental, and so far these have prevented anything like the successful development which would present an entirely new tool to the lighting engineer.

In the field of high brightness there seems to have been little further work on the water-cooled lamp. Most of the effort has been expended on the compact source type, firstly on the production of much larger wattage ratings, and more recently on the improvement of colour rendering. This work has been confined mainly to Great Britain ([3]), ([4]), ([5]), ([6]), although at least for a time the development was taken seriously in Germany ([7]). The concentration of effort on these high intensity lamps—particularly those of large wattage rating—has resulted in substantial progress in three directions. The techniques developed have allowed the exploration of regions of pressure and current density not previously accessible, and this has led to a fairly definite knowledge of the upper limit of luminous efficiency and how this might be achieved ([8]). Similarly the immediate potentialities of the h.p.m.v. discharge as a projection source are now reasonably clear ([3]), ([4]), ([5]). For both types of lamp—those in which high luminous efficiency is the first consideration, and those in which only the brightness is important—as well as for the important class in which neither brightness nor luminous efficiency alone is the sole requirement—substantial improvements in colour have been obtained without unreasonable sacrifice of efficiency ([3]), ([5]), ([6]). In parallel with this experimental work theoretical advances have gone on steadily ([9]). This paper is concerned only with the present state of development of these more recent highly loaded lamps although reference is, of course, made to the tubular type lamps for purposes of comparison.

It should be understood that the commercial application of many of these high intensity lamps is in quite an early stage, and that much of what follows is an account of a state of development rather than one of established commercial practice.

(2) Properties of the Discharge

(2.1) Luminous Efficiency

For general lighting purposes, of course, the luminous efficiency of a lamp is of outstanding importance, and it may also be a significant factor for many types of projection application. For many years it has been realised that the luminous efficiency of the h.p.m.v. discharge increases both with the pressure and with the current density. It is this, for example, which explains the gain in luminous efficiency by the use of vitreous silica instead of glass envelopes in the conventional tubular design of lamp. Silica permits a higher envelope temperature and, therefore, both a higher pressure of mercury vapour and a larger power loading of the discharge column. So long as one is restricted to tubular envelopes in which mechanical stability of the arc is ensured by the proximity of the wall of the envelope, in lamps designed to have a long life and to

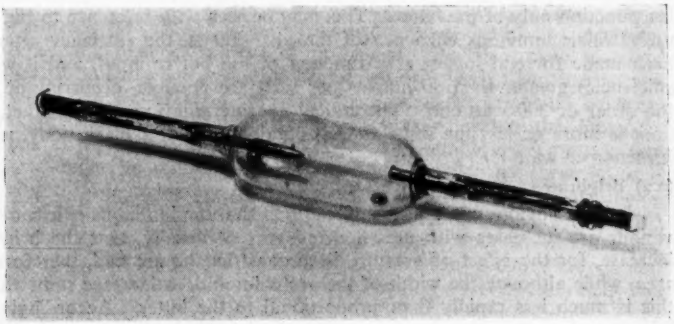

Fig. 2. High efficiency lamp, 1kw.

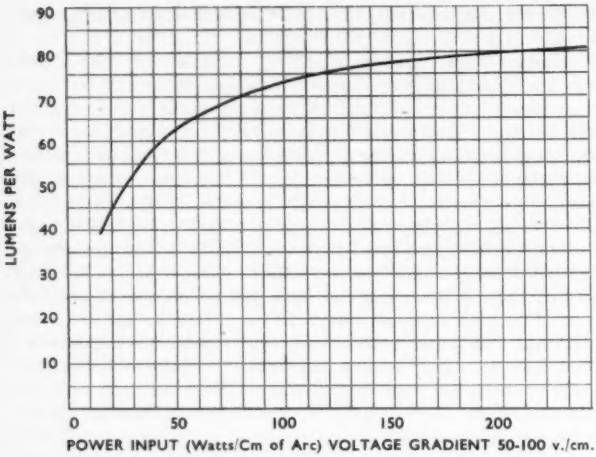

Fig. 3. Instrinsic luminous efficiency of H.P.M.V. discharge.

operate on normal supply voltages the efficiency varies from about 40 lm./w. at 100 watts to perhaps 60 lm./w. at 1 kw. It is, therefore, important to know what is the position when this restriction is removed. This could be effected by using a glass harder than vitreous silica if such a transparent substance were available, or by water-cooling the envelope, which, except in very special circumstances, is extremely inconvenient. In practice, however, it may be achieved by a design of lamp intermediate between that of the compact source lamp, discussed in Section 3.3, and the tubular lamp already mentioned. An experimental lamp of such a type, for example, is shown in Fig. 2. The desired high power input per unit length of arc may be obtained by the use of relatively high pressures of the order of 5 to 10 atmospheres, and arc voltage gradients of the order, therefore, of 50 volts per cm. The short arc length allows the column to remain stable even when the walls of the envelope are removed from its proximity. In this way the limitations of power loading, imposed by the softening point of the material used for the envelope, are effectively removed, and then a range of pressures and power loadings of the arc column may be investigated which would otherwise be impracticable. Exploration of this region by such means has shown that much higher luminous efficiencies are possible than was thought to be the case ([8]). At pressures of some 5 atmospheres or more, the variation of luminous efficiency with pressure is small provided the power input to the arc is maintained constant; accordingly the luminous efficiency is a function only of the latter. This may be seen with reference to Fig. 3 which shows the intrinsic luminous efficiency of the arc, that is, the efficiency after allowance has been made for end losses, as a function of the power input, and it will be seen that efficiencies greater than 80 lumens per watt are possible, occurring at arc loadings of the order of 200 watt/cm. Theoretical considerations suggest, in fact, that the upper limit is more or less the same as that obtainable with a black body, namely about 84 lumens per watt ([8]).

(2.2) Brightness

It is an obvious consequence of the fact that the luminous efficiency of the mercury vapour arc increases with pressure and current density, that the brightness will also increase, for the effect of pressure is to constrict the arc and, therefore, to reduce the area, while although the width of the arc column does increase somewhat with current, this is much less rapidly than proportional to the latter. Accordingly if, for a given

lamp rating, the source size is decreased, so the brightness will increase, always provided, of course, large additional losses are not introduced at the electrodes or elsewhere. A formula expressing this has been given recently (4).

$$\text{Peak brightness (Stilbs)} = 3.0 \times \left(\frac{\text{arc voltage}}{\text{arc length (cms.)}}\right)^{1.5} \times \left(\frac{\text{current}}{\text{(amps)}}\right)^{0.7}$$

and the same results are shown in Fig. 4.

The rapid increase in brightness at the smaller arc lengths is of considerable interest, and immediately raises the question where, if at all, an upper limit to the brightness exists. The other question of more practical import is where difficulties in lamp design place this limit (Section 3.3).

So far as the theoretical upper limit is concerned it is not certain, in fact, that one exists at all, but it is clear that if there is such a limit, it is much beyond anything so far obtained experimentally or likely to be obtained with any of the techniques at present at our disposal.

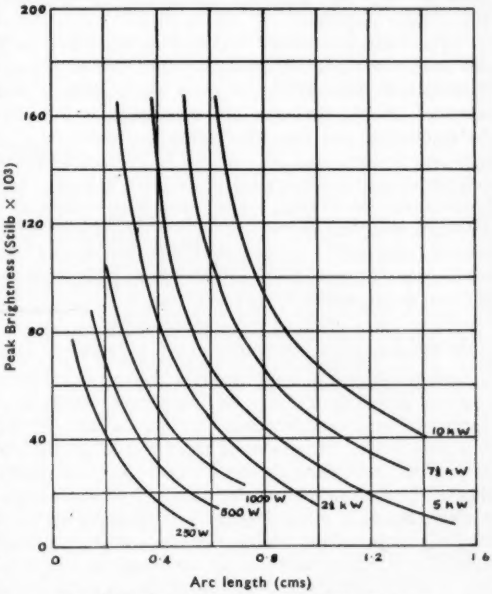

Fig. 4. Peak brightness of H.P.M.V. discharge.

(3.3) Colour Rendering Properties

Many means have been suggested for improving the colour rendering properties of the h.p.m.v. discharge besides those inherent in the operating conditions of the arc itself. The outstanding requirement is, of course, the addition of red to the spectrum, but there are others, and even if one were successful in adding as much red as desirable, the colour rendering might still prove to be unsatisfactory for some applications. Nevertheless, while the red deficiency is so marked, this problem must be dealt with first.

In the discharge itself there are three possibilities which might suggest an improvement. The first is that of altering the relative intensities of the various spectrum lines. The second is that of increasing the background continuous spectrum. A little consideration and experience shows that the first of these is not likely to prove fruitful, and, in fact, although relative line intensities are dependent upon the current and pressure at which the discharge is operated, there is no experimental evidence to indicate that appreciable improvement could be obtained within the limits of operating conditions at our disposal, nor does theory suggest that even outside this region such a result might be realised. The continuous background spectrum is a rather different matter. The operating conditions in which a substantial amount of radiation is in the form of a continuous spectrum are also those which give rise to considerable line broadening, the third factor which might help to produce the modifications required. There are two mechanisms—electron recombination and radiation from loosely bound molecules formed at high pressures—to which this

continuum is due. The first of these increases with current, the second with pressure. That significant modifications to the spectrum take place as the pressure and arc loading are increased is well known, and an approximation to a true continuous spectrum may in fact be obtained [10]. There does not seem much doubt that if the pressure could be increased to, perhaps, 500 atmospheres the colour difficulty would be well on the way to a complete solution. Unfortunately such operating conditions are impracticable, at least at the present time, and it seems amply demonstrated now that for practical purposes the mercury vapour arc alone cannot be expected to give the spectral distribution required.

The consideration of additives is, therefore, of importance, and of these cadmium and zinc are the most obvious. The use of these metals is by no means new, and goes back to the early application of the h.p.m.v. discharge for lighting. At that time, however, the method was not successful; it was not possible to get sufficient red into the discharge, and even the colour correction that could be obtained involved a very high cost in luminous efficiency. In the more recent highly loaded quartz lamps these difficulties largely disappear [3], [5], [6], and it is now known that this is because it is possible to use a much higher partial pressure of cadmium vapour, which not only gives a considerable amount of additional red, but results in a much smaller overall loss of efficiency. In the highly loaded lamps this colour improvement is assisted by the useful amount of line broadening and continuous spectrum present even in the plain mercury lamp.

(3) Lamps

(3.1) General

Of the high intensity lamps with which we are concerned, there are two extremes —those designed to have the maximum brightness possible, and those to have the optimum luminous efficiency. Figs. 1c and 1d may be taken as illustrating these extremes. The arc length of the latter is greater, and the power input per centimetre of arc less than those of the former. But the discharge columns will always be much shorter than those of tubular lamps. Between these two extremes are lamps in which neither luminous efficiency nor brightness is the only parameter of importance.

All these lamps necessarily have a large energy dissipation in a small bulb; the need for vitreous silica as an envelope is one consequence of this concentration of power input, and even so the envelope remains one of the limitations to progress. The properties of vitreous silica are useful also in that its relatively high mechanical strength allows the high operating pressures of vapour on which, as we have seen, the useful properties of the discharge depend. This may range from 5 to 50 atmospheres, according to the power rating of the lamp and the purpose for which it is required. Pressures naturally tend to be higher in the high brightness lamps with the smaller sources there employed, than in the high efficiency lamps.

The use of silica, of course, results in the emission of a certain amount of ultra-violet radiation. There is not as much short-wave energy as might be anticipated, since strong reversal of the 2537 Å resonance line occurs, but there is sufficient, nevertheless, to render it necessary that these lamps should be operated either in an outer glass bulb or in an enclosed fitting.

(3.2) High Efficiency Lamps for General Illumination

In a practical lamp, of course, the overall luminous efficiency is less than that of the arc column alone by an amount which depends upon electrode losses and obscuration by the seals and mounting, and the practical problem is to see to what extent the efficiencies indicated in Section 2.1 can be realised in practice. In this connection it is important to note that the high luminous efficiencies are fundamentally associated with large loadings of the arc and, therefore, with lamps of relatively large rating, as a contrast to the low-pressure sodium lamp and tubular fluorescent lamp

in which the highest efficiencies are obtainable in low-wattage units. The arc lengths must, therefore, be relatively short, and the diameter of the bulb is made as large as possible to obtain the lowest wall temperature consistent with maintaining the necessary vapour pressure. It is clear, therefore, how it comes about that the design leads to something approximating to a compact source lamp (Figs. 2 and 1c, 1d).

The short arc lengths naturally tend to increase end losses, but careful design allows them to be kept reasonably low, and the lamp of Fig. 2, for example, actually has an efficiency of 75 lm./w. With the tubular design of lamp it has been found that the optimum design for any particular rating, so far as regards arc length and envelope diameter, is not at all critical. The same is true of these more highly efficient lamps, and it is possible to vary the arc length over fairly wide limits without a substantial difference of performance. It would not be unexpected, however, that, in

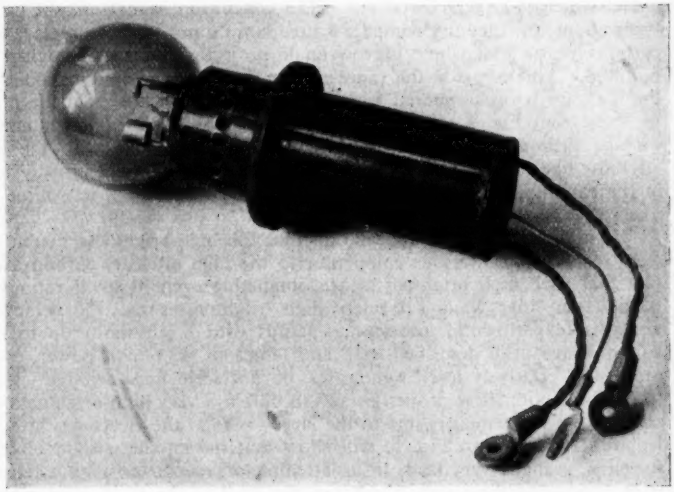

Fig. 5. Single ended high-brightness lamp.

the extreme, when the arc becomes effectively a small high-brightness source, such as in the 5-kw. lamp of Fig. 1c, the overall efficiency is relatively low, of the order of 45 lm./w. As indicated in Section 3.3, losses at the electrodes are considerable in such a lamp, and in a 5-kw. lamp designed to have a high luminous efficiency it would be necessary to reduce these losses, as, for example, is shown in the design of Fig. 1d.

Sufficient work has not yet been done to establish practicable luminous efficiencies for all wattage ratings, but it seems not unlikely that—at least for units larger than 500 watts—it may prove quite possible to associate efficiencies of 70 lm./w. or more with long lives and reliable operation. Lamps may be designed for either A.C. or D.C., the electrode construction being different in the two cases; the problems connected with life, lumen maintenance and adaptability to the usual circuit requirements on either A.C. or D.C. are not substantially different from those of tubular-type lamps.

The commercial future of these high-efficiency lamps will be decided largely by economic factors. It is likely that a lamp of the design of Fig. 1d will always have a shorter useful life than a tubular lamp of the design of Fig. 1b. On the other hand it uses substantially less of the expensive vitreous silica and should cost much less to manufacture. Perhaps tubular lamps will continue to be used for the smaller, whereas

the higher efficiency lamps will be used in the large wattage ratings, although it is too early to assess the position at all critically.

(3.3) High-Brightness Lamps

Compact source-lamps have been made experimentally in sizes varying from 125 watts to 50 kw., and up to 10 kw. they have either been made generally available on the market or used in large-scale commercial tests ([3]), ([4]), ([5]), ([6]). The design of all these lamps is essentially similar, although they are made in the double-ended form shown in Fig. 1c or in the single-ended, shown in Fig. 5. The silica bulb diameters range from about 30 mm. for the 250-watt lamp to 150 mm. for a 25-kw. lamp. The overall length of a double-ended 25-kw. lamp is some 600 mm.

The practical upper limit to the brightness proves to be not much above 100,000 candles/sq. cm.—except in certain rather low-wattage lamps ([11]), ([4]). It is of interest that this figure is close to that of the peak brightness of the high-intensity carbon arc, a fact which is largely fortuitous. The conclusion is that, except perhaps for special applications, the mercury compact-source lamp is not likely to replace the high intensity carbon arc, at least where narrow angle projection and small high-power sources are required. This is made the more certain by the poor colour-rendering properties of the mercury lamp compared with that of the carbon arc. On the other hand it may be seen from Fig. 4 that very high brightnesses are possible in lamps of quite low wattage rating, brightnesses, in fact, quite unobtainable with the carbon arc with anything like the same expenditure of power. This fact has already found recognition in the early marketing of the 250-watt and 500-watt compact-source lamps, and it is likely that further applications will be found in this region.

It may at first sight appear odd that the high-brightness mercury-lamp does not seem to be a more serious competitor to the high intensity carbon arc in view of the fact that such high brightnesses are obtainable even in small ratings. The difficulty is, however, that while extremely high brightnesses may be achieved at quite low wattages (experimental low-wattage lamps with brightnesses up to 200,000 candles/sq. cm. have been described) ([11]), and lamps of very high power, even of 50 kw. or more with relatively low brightnesses, do not seem unreasonable ([3]), ([4]), it is difficult to combine both these properties and to obtain a very high-brightness source with high power. This is primarily due to the large losses at the electrodes in lamps of short arc length. Reference to Fig. 1c will show that the anode, a solid block of unactivated tungsten, is made very large in an attempt to prevent too high a temperature, since it is the fusion of the anode which sets the limit to the total energy which can be concentrated in a short arc. Although lamps for A.C. operation have intermediate electrode losses between those of the anode and cathode in a D.C. lamp, the limit appears to be at much about the same value of brightness. Many attempts have been made to overcome this limitation ([3]), but so far there seems to be no successful solution.

The large electrodes necessary to dissipate the losses naturally give rise to difficulties in employing lamps efficiently in optical systems. With short arcs the obscuration caused by these electrodes may reduce the overall efficiency by a very considerable amount. These disadvantages may be minimised in various ways; by the use of an axial alignment of the lamp, or—as Aldington has described ([4])—by the use of a right-angle electrode system. Of course, it is not always that a very small source is required. It is more usual that provided it is not larger than some given size, which is dependent on the optical system, it does not matter how near to this size it is. In these quasi-projection applications it is the total light output rather than the brightness that is important, and then the electrode obscuration is one of the factors to be considered in association with the luminous efficiency. It is in these applications where a large source is no disadvantage that the mercury-lamp of high power may play an important role. Another consideration bearing on the type of source best suited to a particular use is, of course, its shape. In a compact-source lamp the source may be

made approximately spherical at the shorter arc lengths, but as end losses are reduced and the arc length increased the shape of the source becomes elliptical. In Section 5.1 is mentioned an application where this property has been employed.

As might be expected in lamps of very large power—the problem, in fact, becomes serious in ratings above 25 kw.—large quartz bulbs present difficulties both in their increasing fragility with size and also in lamp fabrication. It is this, in fact, at the moment, which tends to serve as a limit on the largest rating of lamp which can be made, although in these large lamps, since the pressure must be kept relatively low, and the source, therefore, relatively large, the actual source-brightness does not increase substantially beyond the upper limit mentioned above.

There is no space here to describe the interesting work which has gone towards developing a high-current seal through quartz. Some of this work has been described elsewhere [3], and it must suffice to indicate that such seals capable of carrying up to 500 amperes can now be made successfully.

(3.4) Colour-modified Lamps

The design of a lamp of the kind considered is not substantially different whether or not it includes cadmium or cadmium and zinc with the mercury. There are, of course, many finer points of detail, but, for example, the lamps shown in Figs. 1c and 1d could, so far as their appearance and dimensions are concerned, be either plain mercury or colour modified.

For general lighting purposes experimental lamps of 500 watts to 1 kw. rating have been made with luminous efficiencies of 45 to 50 lm./w. and with two-thirds of the red content of daylight [5]. Whether these lamps will be widely used for street lighting and for industrial applications will again depend largely on the question of economics.

In the field of high brightness it does not yet appear possible to make lamps suitable for film projection (Section 5.1), but the use of lamps with larger sources and employing the full degree of colour correction possible is likely. (Section 5.2) [5], [6], [12]. The brightness is reduced by the addition of cadmium and zinc to an extent which depends on the source size, pressure and other conditions. This is due partly to lower efficiency, and partly to increased spreading of the arc by the cadmium and zinc. This decrease in some circumstances is 30 per cent. or more, but in the smaller-source higher-pressure type of lamp it may be 10 per cent. or even less.

(4) Operating Characteristics

In broad terms, the electrical properties of these lamps are similar to those of tubular lamps, and as a result of the extensive use of the latter for general illumination, are fairly widely understood.

(4.1) Arc Voltage Drop

The voltage across the arc in a plain mercury lamp increases with pressure of mercury vapour and, therefore, unless the amount of mercury is restricted, will vary with power input to the tube; and in general, both voltage and power input will then be dependent on the ambient temperature. These facts are somewhat modified for lamps containing cadmium or zinc, but, broadly speaking, although the necessity for limitation is not so critical, the same considerations hold.

For reasons of overall efficiency, it is always desirable to keep the arc voltage as large as is consistent with other requirements. Freedom from extinction usually limits this to 60-70 per cent. of the supply voltage on A.C. mains. In lamps for general lighting, where overall efficiency is the most important consideration, lamps are always designed to have the maximum arc voltage. This is not always so, however, with high brightness compact-source lamps. Here, requirements of short arc length to obtain a small source,

together with an upper limit on arc voltage gradient, imposed by the mechanical strength of the bulb, have usually resulted in the use of a total arc voltage drop less than that necessitated by freedom from extinction. Thus, in the small-source compact-source lamps, the arc voltage drop is of the order of only 70 volts even when the lamps are designed for operation on 240 volt supplies.

(4.2) Run-up Time

There is in high intensity lamps the interval common to all h.p.m.v. lamps between starting and the attainment of full operating conditions. This may vary from two to 15 minutes according to the particular design and the conditions in which the lamp is operated. The inconvenience associated with this property has led to much work in the effort to overcome the difficulty. A "simmering" arrangement such as that mentioned in Section 5.2 is perhaps the most successful solution at the moment. The lamp is kept up to full temperature by means of lagging and a much reduced expenditure of power, which may be obtained entirely by heat developed in the arc itself at a reduced current, or by external heaters, or by a combination of both. The reduced "simmering" power depends upon the particular application, and varies from 5 per cent. to 50 per cent. of the full rating.

(4.3) Hot Restarting

If an h.p.m.v. lamp is extinguished while in the high-pressure state, and the supply voltage is not restored before the vapour becomes substantially deionised—intervals of the order of one second are usually sufficient—it requires several thousand volts to restart the arc. If the normal supply voltage only is available the period before the lamp cools sufficiently to be restarted may be 10 or 15 minutes, and to this must be added the run-up time before the lamp is again ready for use. This is, perhaps, the most serious difficulty associated with the practical application of these lamps, and there has been much effort spent in finding the best means of dealing with the difficulty.

The problem has been solved in several different ways. In one of these a pulse or damped oscillation with a peak of several thousand volts is produced either by discharging a capacitor through, or breaking a D.C. current in, the primary of a transformer. This voltage is applied to the terminals of the extinguished lamp, and is prevented from short-circuiting through the live mains by a suitable choking inductance. There are obviously many possible variants of this principle.

A second method which has been used with some success is that of producing by means of a small high-ratio step-up transformer a low-power A.C. voltage with an amplitude sufficient to start the tube. As soon as this takes place, the transformer is automatically removed from the circuit. If this circuit is to be used on D.C., it is necessary to employ a vibrator or some other device to produce the required A.C. The many variants here are concerned mainly with the means adopted to remove automatically from the circuit the high-voltage transformer.

Both these methods may be modified by applying the high voltage, not to the main electrodes of the lamp, but to one main electrode and an auxiliary electrode situated near to it. The function of the auxiliary arc is partly that associated normally with such aids to starting. Since in these lamps, however, it does not necessarily follow that, even with a discharge across the auxiliary gap, the main arc will start on normal supply voltages, it is usual, by means of suitable design of circuit to share the high voltage between the auxiliary gap and the main arc, so that the latter starts immediately the former is in operation.

The advantage of the auxiliary electrode is that it allows the use of a much lower restarting voltage; the disadvantage—and in this type of lamp a serious one, where the strength of the bulb is so important, and where the introduction of seals at the best is a difficult problem—is that it becomes necessary to introduce another seal through the envelope. The use of a short pulse rather than a steady A.C. voltage supplied by

an auxiliary transformer has the advantage that the amount of energy in the pulse may be made so small that it is not dangerous to life while still being sufficient to start the arc. A further advantage is that the frequencies involved in the pulse may be of the order of megacycles, so that earthing by means of capacitors is effective. This is very useful in circumstances where a direct connection of the fitting to earth is not possible.

A third principle involves the use of a heated auxiliary electrode, and—at least in a number of applications—avoids the use of high voltage altogether.

Which of these methods of restarting will ultimately prove the best it is too early yet to decide.

(5) Applications

It is possible here to mention only very briefly one or two applications of these lamps.

(5.1) Film Projection

This is essentially an application where the source brightness is the important parameter. For 35 mm. projection where power inputs of the order of 3 kw. are usually used, it would be expected from what has been said in Section 3.3 that the mercury lamps have an overall efficiency about the same as that of the high intensity arc. When, however, the lamps are given the best colour correction that can so far be obtained with cadmium and zinc, the screen illumination is less than that given by an arc with the same power consumption, and even then the colour rendering of the mercury lamp is not so good.

For 16 mm. projection where usually tungsten filament lamps are used, the same conclusions hold so far as satisfactory colour rendering is concerned. Here, however, the high brightness achievable in low wattage mercury lamps may be employed, and this, combined with the use of a source the same shape as the gate, makes possible with plain mercury lamps screen illuminations five times that obtained with a tungsten filament lamp of equivalent wattage. An interesting application of intermittent operation [5] suggests that this figure may again be doubled.

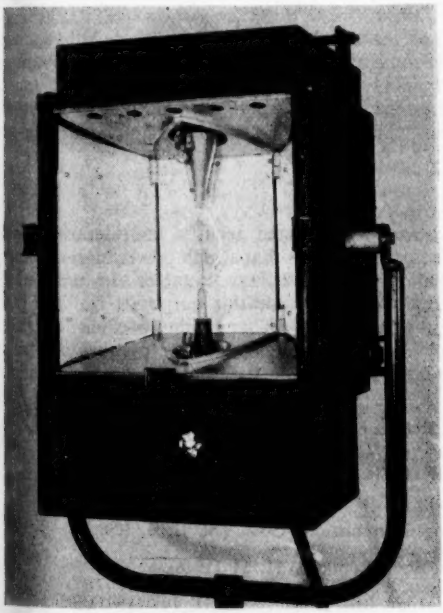

Fig. 6. Motion picture set lighting unit.

(5.2) Film Studio Illumination

During the last few years, the increasing use of the colour film has made it essential that any lamps used for the lighting of motion picture sets should be able to give colour rendering suitable for the taking of Technicolor film. Since this requirement can be met and the difficulties associated with the time of run up and hot restarting can be overcome, the serious disadvantages of the carbon arc, particularly the noise, fumes and necessity for periodical replacement of carbons, make it likely that the

mercury lamp will be widely used in the film industry (5), (6), (12), (13).

There are two main types of unit employed for set lighting: That giving a more or less concentrated beam, the so-called "spotlight," and that giving a broad distribution. Neither of these uses the narrow-angle beam which necessitates a very small source, so that in both classes of fitting, one is able to use the longer arc-length lamps. As a result, the overall efficiency of units employing mercury lamps compares favourably with that of units using the conventional carbon arc.

In Great Britain, film tests have been made using mercury lamps of ratings varying from 1 to 10 kw., and at present 2½-kw. and 5-kw. units are being used in film production.

As an example of the type of fitting employed, Fig. 6 shows a photograph of a 2½-kw. projector used for background lighting. It is a self-contained unit with built-in ballast resistances, control and starting gear. The lamp is not of the highest brightness type, having a relatively large source and operating with a luminous efficiency of some 45 lm./w. and some 10 per cent. red.*

The fitting is designed to take account of the various lamp characteristics mentioned in Sections 3 and 4. The convection currents, for example, are so controlled as to give uniform cooling of the quartz envelope and to keep the seals at as low a temperature as possible. To overcome the difficulty of the run-up time, the principle of "simmering" is employed. When not in use, the lamp is operated at 1 kw. inside a metal enclosure serving the double purpose of providing a shutter for the lamp when it is not in use, and also maintaining the temperature of the envelope so that the lamp gives its full illumination immediately the normal power of 2½ kw. is restored. The shutter is opened automatically at the same time and thereafter serves as part of the mirror system. A circuit which provides a short high voltage pulse is also incorporated, although in this application this is not required to provide "hot-starting" under all conditions.

The fitting may be tilted at any of the usual angles of operation, although no magnetic control of the arc is used. In some applications of these lamps such magnetic control is found necessary. There are many variants in the design of such projectors, and Bourne and Beeson (6) have described a 5-kw. spotlight unit which serves as another illustration of the manner in which these lamps are adapted for film-set lighting.

(5.3) High-Bay Lighting

In situations where large areas have to be lighted from a considerable height such as railway yards or high bays in factories, it seems that a high-power high-efficiency lamp of the type shown in Fig. 2 may well prove very suitable. In the United States a 3-kw. tubular lamp some 3 ft. long is used for this purpose (14). The gain economically with such large units is not only in the higher luminous efficiency which may, nevertheless, be considerable, but also in the reduction of the number of fittings necessary which would in turn effect a large reduction in the capital cost of installation.

References

(1) Bol, C., Elenbaas, W., de Groot, W., De Ingenieur, **83,** 83 (1935).
Elenbaas, W., Physica, **2,** 807 (1935).
Elenbaas, W., Zeit für Tech. Phys., **17,** 61 (1936).
(2) Francis, V. J., and Wilson, G. H., Trans. Illum. Eng. Soc. (London), **4,** 59 (1939).
Ewest, H., Internationale Beleuchtungs-Kommission, 1939, Vol. II, p. 129.
(3) Nelson, E. H., G.E.C. Journal, **14,** 73 (1946).
(4) Aldington, J. N., Trans. Illum. Eng. Soc. (London), **11,** 11 (1946).
(5) Francis, V. J., and Stevens, W. R., Jour. Inst. of Elec. Engs., **94,** 423 (1947).
(6) Bourne, H. K., and Beeson, E. J. G., Jour. Brit. Kinem. Soc., **11,** 107 (1947).

* As measured by the transmission through a Wratten filter No. 25.

(7) Rompe, R., and Thouret, W., Zeit für Phys., **17**, 377 (1936).
Rompe, R., and Thouret, W., Zeit für Phys., **19**, 352 (1938).
Rompe, R., and Thouret, W., Das Licht, **14**, 73 (1944).
(8) Francis, V. J., Isaacs, G. G., and Nelson, E. H., Phil. Mag., **37**, 789 (1946).
(9) Elenbaas, W., Physica's Grav., **9**, 53 (1942).
Francis, V. J., Phil. Mag., **37**, 433 (1946).
Francis, V. J., Phil. Mag., **37**, 653 (1946).
Elenbaas, W., Philips Res. Rep., **2**, 20 (1947).
(10) Elenbaas, W., Physica, **3**, 859 (1936).
(11) Brit. Pat. No. 582,408.
(12) Davies, L. J., Proc. of the Convention of the I.E.S. (London), 1946, p. 31.
(13) Bourne, H. K., B.T.H. Activities, **19**, 181 (1947).
(14) Kahler, W. H., Westinghouse Engineer, **4**, 144 (1944).

Additions to the List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members.

CORPORATE MEMBERS:—

Baker, G. A. .....6, Prospect Vale, Heald Green, Cheadle, CHES.
Brazington, E. .....2, Church Meadows, Gt. Gaddesden, Hemel Hempstead, HERTS.
Dunn, N. .....91, Green Lane, Middlesbrough, YORKS
Edwards, W. H. N. ....."Woodside," Lisvane, Cardiff, GLAM.
Fairhurst, W. .....246, Pershore Road, BIRMINGHAM, 5.
Gummer, A. M. .....26, Ladygate Lane, Ruislip, MIDDX.
Harper, T. S. .....P.O. Box 482, Johannesburg, S. AFRICA.
Hill, L. C. .....3, West Drive, Harrow Weald, MIDDX.
Hills, C. L. .....28, Wilbury Gardens, Hove, SUSSEX.
Hyde, H. J. .....Siemens Electric Lamps and Supplies, Ltd., 81, Dale Street, LIVERPOOL.
Jeffery, S. N. .....29, Montrose Avenue, Welling, KENT.
Kent, J. C. W. .....37, Wenallt Road, Rhiwbina, CARDIFF.
Kinnell, S. D. .....27, Beechwood Gardens, Mossend, LANARKS.
Knowles, J. E. .....7, Warley Road, Firswood, MANCHESTER, 16.
Law, A. .....152, Orchard Road, Erdington, BIRMINGHAM.
Martin, W. K. .....1a, Coldwell Terrace, Felling, GATESHEAD, 10.
Mills, L. V. .....18, The Ridge, Purley, SURREY.
Plowman, F. .....4, Greenwood Avenue, Linthorpe, Middlesbrough, YORKS.
Riding, R. H. .....91, Church Lane, Sale, MANCHESTER.
Riley, M. A. .....36, Rodway Road, Sundridge Park, Bromley, KENT.
Schofield, A. N. .....General Electric Co., Ltd., Magnet House, Kingsway, LONDON, W.C.2.
Shortt, J. S. ....."Cranbrook," Homedale Estate, Prudhoe - on - Tyne, NORTHUMBERLAND.
Stephenson, C. H. .....1, John Street, Stroud, GLOS.
Thompson, T. .....Victoria Works, GATESHEAD, 8.

TRANSFERRED TO CORPORATE MEMBERSHIP:—

Phillips, C. McN. .....4, Grantchester Court, Watford, HERTS.
Radley, L. J. .....71, Laird Road, Wadsley, SHEFFIELD.

Special Lighting Units for the Flight Decks of Aircraft Carriers

By H. H. MATTHEWS *(Member)*

Summary

An account is given of the development of " Pillar Lights " which formed part of the equipment to enable aircraft to be landed on a darkened aircraft carrier.

The flight deck lighting system in aircraft carriers is designed to enable a darkened carrier to operate aircraft at night with the least risk of detection from enemy ships or aircraft, consistent with making it as simple as possible for the pilot to land-on or take-off from the flight deck.

The provision of a properly designed system of night flying and signal lights for aircraft carriers assumed very great importance in the year 1936 and onwards when the ARK ROYAL and ILLUSTRIOUS class carriers were being designed and constructed. A fair amount of experimental work had been previously carried out, during the period 1930-36, in the early carriers GLORIOUS, EAGLE, etc., which helped in deciding what was considered to be an ideal system of lighting for the types of aircraft used by the the Navy just prior to the war. Due to the continual introduction into the Royal Navy of more modern types of aircraft, with consequent changes in flying technique, there is always a need, however, for new designs of lighting units to be produced to keep the system up to date.

The present system of lights is divided into three groups, viz:—

(i) *Take-Off lights* to facilitate aircraft taking-off from the flight deck.

(ii) *Approach lights* to guide aircraft towards a location near the carrier where the landing lights and signals can be seen.

(iii) *Landing lights* which assist pilots during the final landing-on stages.

The lights of all three groups are designed to be visible to pilots, while flying, through definite horizontal and vertical arcs. It is not proposed to give full particulars of the purposes, angles of visibility, etc., of the various lights used in these groups as much of this information is regarded as confidential.

This article is more intended to describe certain of the design principles which were employed in order that the lighting fittings would comply with the stringent requirements laid down by the Naval Air departments. It would be a rather lengthy story to describe fully all of the illumination, electrical and mechanical problems involved in the design of the flight deck lighting installation, therefore, one interesting example will be cited of the special lighting fittings which have been evolved for this purpose by the Lighting Design Section of the Director of Electrical Engineering, Admiralty.

The development of the " Pillar Light " was begun in 1937, when a need arose for lighting units 6 ft. high by 1½ ft. wide, three such fittings to be spaced some 50 ft. apart along each side of the landing area on the flight deck as an additional aid for pilots landing on the carrier at night-time.

It was considered that the pillar lights should conform, as nearly as possible, to the following requirements :—

(a) The entire area of the front of the pillar light (6 ft. × 1½ ft. wide) should be

The author is in the Department of the Director of Electrical Engineering, Admiralty. Manuscript received January 2, 1950.

uniformly lighted at an intensity which would enable the pillars to be easily visible at a maximum range of three miles.

(b) The lights should be screened so that they would not be seen by enemy shipping or by enemy aircraft flying outside the specified angles of cut-off for the screening which were as follows :—

Horizontally—from 45 deg. outboard to 45 deg. inboard, i.e., 45 deg. either side of the carrier when the lights are showing aft.

Vertically—Lower limits of cut-offs :—

3½ deg. at 45 deg. outboard, and 45 deg. inboard.

2 deg. at the fore and aft line of the ship.

Upper limit of cut off :—

30 deg. throughout the whole horizontal arc.

(c) The lights should be collapsible, in the sense that they could assume a prone position, if accidentally struck by the wing of a landing aircraft or be placed thus when not in use. In their "lying down" position the projection of the fittings above the flight deck should be no more than 1½ ft.

(d) The light should be so constructed that they would be able to withstand the impact of an aircraft, weighing several tons, landing at a speed of 60 miles per hour relative to the ship's speed, without causing any considerable damage to the pillar lights themselves or the aircraft. Also, the construction and materials used in the fittings should be capable of withstanding very arduous weather conditions.

The first stage in the development of this project was to produce a simple wooden light box having a uniformly illuminated front panel 6 ft. high × 1½ ft. wide so that trials could be carried out by pilots to gain some idea of the actual illumination value

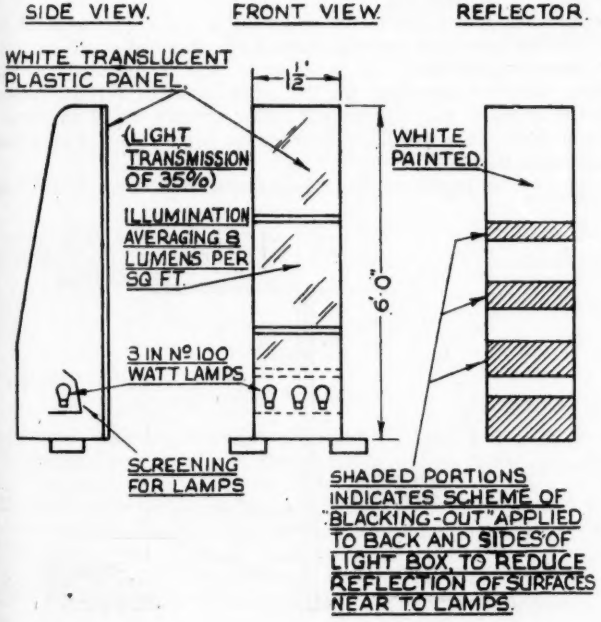
SIDE VIEW.
FRONT VIEW.
REFLECTOR.
WHITE TRANSLUCENT PLASTIC PANEL.
1½'
(LIGHT TRANSMISSION OF 35%)
WHITE PAINTED
ILLUMINATION AVERAGING 8 LUMENS PER SQ FT.
6'0"
3 IN Nº 100 WATT LAMPS
SCREENING FOR LAMPS
SHADED PORTIONS INDICATES SCHEME OF "BLACKING-OUT" APPLIED TO BACK AND SIDES OF LIGHT BOX TO REDUCE REFLECTION OF SURFACES NEAR TO LAMPS.

Fig. 1.

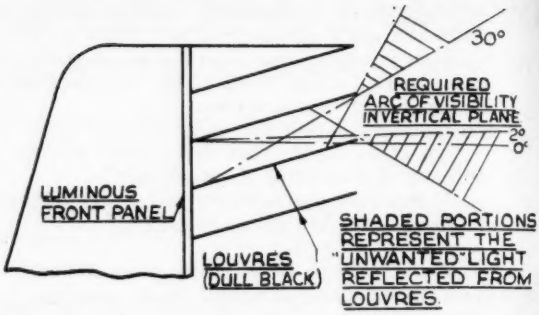

Fig. 2.

they would require. The light box, which was designed for the purposes of these trials, is depicted in Fig. 1. The lamps, as will be seen from this sketch, were situated near to the bottom of the light box as they would then be close to the point where the fitting, in its final form, would be pivoted to make it collapsible.

It was found that adequate illumination for the worst visibility conditions which could be expected was obtainable with three 100-watt, 35-volt lamps in a horizontal row, as shown. These lamps provided an illumination of approximately 8 lumens per sq. ft. over the surface of the panel. In practice, the lamps would be dimmed as necessary from a flight deck lighting-control switchboard to suit any prevailing state of night visibility conditions. Uniform illumination of the front panel was obtained by screening the lamps and by blacking-out strips of decreasing width on the back-reflector board and sides of the light box.

The next stage in development was to design screening for the illuminated front panel which would prevent any light showing outside the specified angles of cut-off whilst allowing as much as possible of the panel to be seen by pilots flying within these arcs. To design accurate screening for the large luminous surface presented by the front of the pillar (6 ft. x 1½ ft.) proved rather difficult as, at the time the job was undertaken in 1937, there had been no previous designs of a similar nature on which one could base ideas.

A louvred arrangement as shown in Fig. 2 below was tried first. It was found,

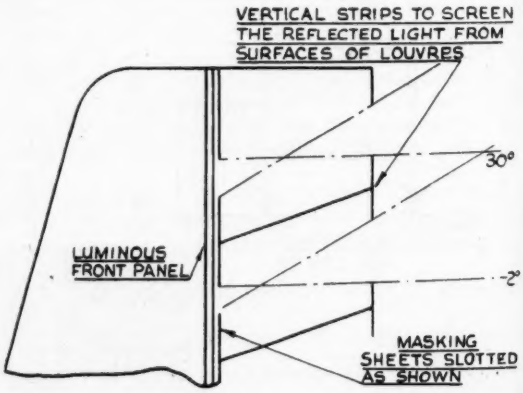

Fig. 3.

however, that although the louvres were coated with dull black paint, a fair amount of light was reflected from them, thus producing zones of low intensity light visible for considerable distances outside the specified cut-off angles. Also, with the louvred arrangement it was difficult without resorting to curved louvres, to fulfill the requirements for the lower vertical cut-off, viz:—2 deg. when viewed from the aft end of the ship and 3½ deg. at 45 deg. inboard and outboard. A further disadvantage

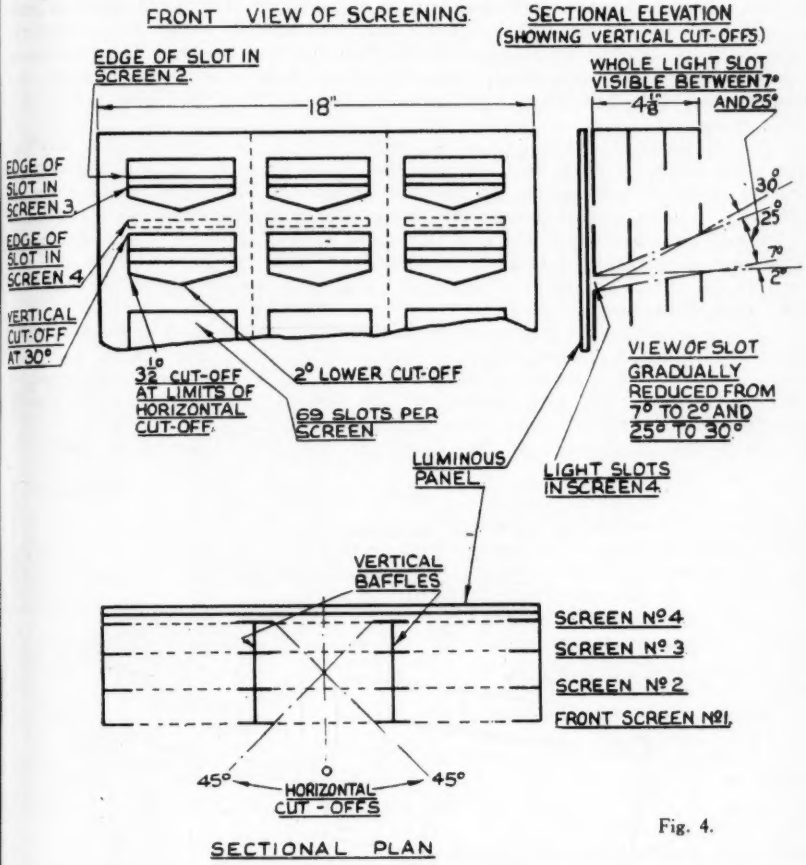

Fig. 4.

of this simple screening was that, if regarded in the vertical plane, the whole of the area of the light source between the louvres would be visible only when a pilot was at exactly the same angle of elevation as the louvres themselves. Should the pilot deviate at all from this angle of elevation the light source would be reduced in size due to portions of it being obscured from his view by the edges of the louvres.

Endeavours were made to eliminate these troubles by modifying the screening as shown in Fig. 3. This comprised a slotted masking sheet placed in front of the luminous panel, the slots in the masking sheet each being regarded as separate small

light sources for the purposes of screening. The outer edges of the louvres were fitted with vertical strips, as shown, to give the vertical cut-off angles required and also to trap as much as possible of the unwanted low intensity light reflected from the surfaces of the louvres. These vertical strips, however, did not entirely satisfy the latter purpose; also, with the general form of construction needed the light slots in the masking sheet had to be spaced rather widely apart in the vertical plane, which meant that a summation of the total area of the light source exposed to the view of a pilot represented only a very small portion of the actual area of the luminous panel.

It was then found that the unwanted reflected light could be satisfactorily eradicated by adopting the form of construction shown in Fig. 4. The arrangement of four vertical screening sheets, each with slots of increasing size as shown, successively acted as light traps with the result that not even one faint ray of stray light escaped.

In designing this screening an important point to be kept in mind was that the whole of the available light source in the vertical plane should be visible throughout as much as possible of the specified vertical cut-off angles (viz:—2 deg. to 30 deg.). The vertical dimensions of the slots in the masking sheet were made $\frac{3}{4}$ in. high and the slots in the front screening sheet $1\frac{7}{8}$ in. high which enabled the light slots in the masking sheet to be wholly seen between vertical angles of 7 deg. and 25 deg.; from 25 deg. to 30 deg. and 7 deg. to 2 deg. the view of the light slots was gradually reduced to zero.

The screening in the production models was made from sheets of black synthetic resin bonded board. This material is light in weight and rather flexible, so that an impact with a landing aircraft would not be so damaging as if sheet metal screening had been used. The total number of light slots in each screening sheet was 69, arranged in 23 horizontal rows, three slots per row, as depicted in Fig. 4.

With the arrangement of three slots per row it was possible to obtain the

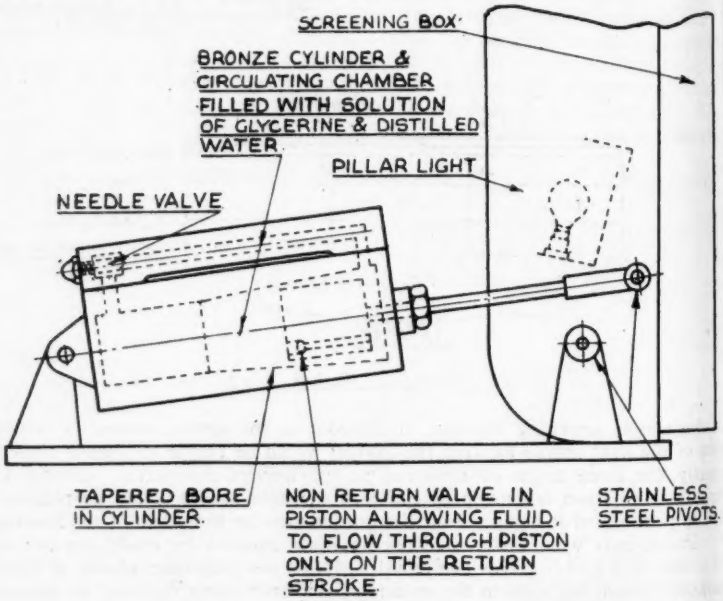
SCREENING BOX
BRONZE CYLINDER & CIRCULATING CHAMBER FILLED WITH SOLUTION OF GLYCERINE & DISTILLED WATER
PILLAR LIGHT
NEEDLE VALVE
TAPERED BORE IN CYLINDER.
NON RETURN VALVE IN PISTON ALLOWING FLUID TO FLOW THROUGH PISTON ONLY ON THE RETURN STROKE
STAINLESS STEEL PIVOTS

Fig. 5.

specified horizontal angles of cut-off (45 deg.—0—45 deg.) by means of a screening box having a projection of only 4½ in. from the front of the luminous panel. Vertical strips were fitted between each of the vertical rows of slots to prevent light from adjacent slots being seen beyond the 45 deg. horizontal cut-off angles. The slight "V" shaping at the bottom edge of the slots in the front screening sheet (shown in sketch below) is for the purpose of cutting off the light at 3½ deg. vertically at the limits of the horizontal cut-off angles, viz. at 45 deg. inboard and outboard; the correct slope of the "V" shape was solved geometrically.

It was now necessary to devise ways and means of rendering the pillar perfectly stable when subjected to high velocity winds as experienced on the flight deck, yet freely pivoted so that it could be easily "struck down" into a prone position if hit by a landing aircraft. This was accomplished by means of the damper arrangement shown in Fig. 5, the pillar being maintained in a vertical position by the pressure of the fluid behind the pistons.

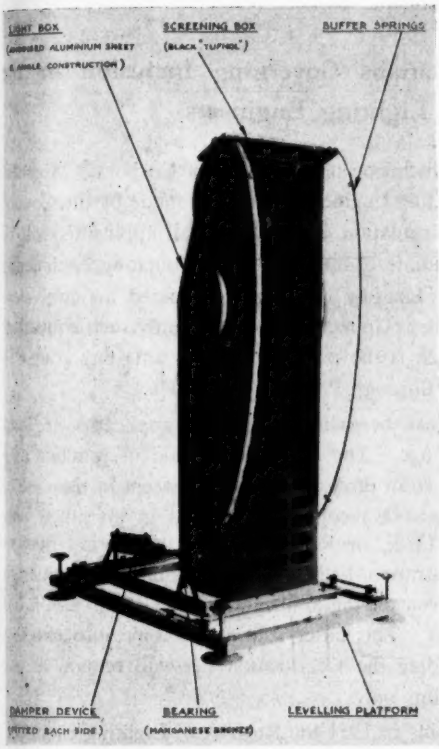

Fig. 6. The 'Pillar Light.'

The pillar being pivoted well below its centre of gravity had a natural tendency to capsize, which assisted it in falling when struck by an aircraft. It will be seen from the sketch (Fig. 5) that the cylinders of the dampers were taper bored for about two-thirds of their length; therefore, the pressure against the piston's movement was lessened for the first portion of its travel, which enabled the pillar to fall at a fast rate to an angle of 45 deg. or thereabouts. When the piston passed the tapered portion of the cylinder and entered the parallel bored portion the pressure against its movement increased and the final part of the pillar light's fall was slow and well controlled.

The pillar light in its finally manufactured form is shown in Fig. 6. As mentioned earlier, three of these lights were fitted along each side of the landing area on the flight deck. The spacing of the three lights was so arranged that a pilot, flying at the correct angle of approach to descend on the flight deck, would see the top of one pillar joining the bottom of the next one behind it, thus giving the effect of a continuous strip of light. This, however, was not their prime purpose, they were mainly useful in enabling a pilot to orient his aircraft relative to the carrier's deck and thus make a level approach. In addition, because of their known height the pilot gained some idea of his distance from the carrier.

The author wishes to thank the Director of Electrical Engineering, Admiralty, for permitting the publication of this paper.

Register of Lighting Engineers

The Council have accepted the following applications for inclusion on the Register of Lighting Engineers :—

W. Berry, W. Browning, E. R. Hems, H. Hewitt, M. C. Hughes, A. H. Olson, D. F. Pierce, P. L. Ross, T. M. Stewart, E. G. R. Taylor, J. Connell Watson.

Amendments to the Regulations Governing Inclusion in the Register of Lighting Engineers

New regulations governing the inclusion of the names of Corporate Members of the Society in the Register of Lighting Engineers have been made by the Council following the lapse of the former Regulation 6. In future all applicants will be required to have passed the intermediate examination in illuminating engineering of the City and Guilds of London Institute or to have obtained an equivalent qualification approved by the Council. (Up to the present the only such equivalent qualification approved by the Council is the passing of a full time day course in illuminating engineering held at the Borough Polytechnic in 1946.)

A minimum age qualification has been introduced and applicants are now required to be at least 25 years of age. The qualifying period of practice as a lighting engineer has been increased from three to five years, except in the case of applicants who have already obtained a recognised standard in an allied field (e.g., corporate membership of the I.E.E. or R.I.B.A.) when this period may be reduced to three years. The Registration Fee is now two guineas which must accompany the application; in the event of the application being unsuccessful one guinea is returnable to the applicant. This latter ruling will come into effect as from January 1, 1951. Until that date the Registration Fee will remain at one guinea payable by successful applicants only.

It is also announced that beginning in 1951 the Register of Lighting Engineers shall be printed annually (probably about April) and a copy sent to each member whose name is entered on the Register at the time of printing. To meet the cost of printing and distributing the Register, Corporate Members whose names are included on the Register will be required to pay an annual charge of ten shillings payable on January 1 each year. Only the names of those who have paid this sum will be included in the published Register.

Full details of the revised regulations may be obtained from the Secretary.

Printed by
ARGUS PRESS, LTD.,
Temple-avenue and
Tudor-street,
London, E.C.4,
England.